INFLUENCE OF FOOD UPON THE BACTERIAL FLORA OF THE SMALL INTESTINE *

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THE BACTERIOLOGIST'S interest in problems of nutrition has been concerned with the detection of harmful bacteria in food and the methods of preventing such bacteria from contaminating food. After studying the normal bacterial flora in the small intestine we have come to the conclusion that the endogenous bacterial life within the lumen of the intestinal tract can change its location and react harmfully to the body as a result of diet, without the invasion into the digestive tract of foreign bacteria. The upper half or two-thirds of the small intestine is slightly acid in reaction and is relatively free of bacteria. The lower part of the small intestine is slightly alkaline in reaction and has a rich bacterial flora, resembling the types found in the feces. The upper part of this tract is a specialized digesting and absorbing area.

We are inclined to believe that the proper acidification of food in the stomach is necessary to maintain a slightly acid reaction in the upper portion of the intestinal tract. The free acid of the gastric contents is quickly neutralized in the duodenum by the alkaline pancreatic and hepatic secretions, the bound or absorbed acid is released more slowly and accounts for the predominance of hydrogen over hydroxyl-ion in the contents of the upper part of the intestinal tract. From our experimental work we have always found the contents of the lumen of the intestinal tract to contain a fecal type of bacterial flora, when it was alkaline in reaction. The results were the same no matter what method was used to alkalinize the intestinal tract. Two general methods have so far been employed—one is the depression of gastric secretion by the elevation of the temperature of the experimental animal. This leads to an alkaline reaction of the intestinal tract, and the fecal flora extend up to the stomach and many times into the gastric lumen. The other method has been to inject alkaline buffered solutions into the lumen of the small intestine. This has led to the same change in the bacterial flora.[1, 2] When the bacteria are given by mouth, suspended in acid buffered solutions, they seldom, if ever, ap-

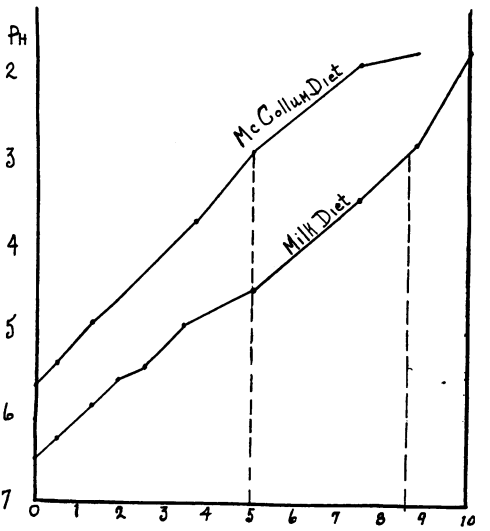

CHART I—Results of experiment in condensed form

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pear in the caecum, but when given with alkaline buffered solutions they appear in the caecum within thirty minutes after ingestions and persist for several hours. This is due to a temporary alkalinization of the small intestine with the alkaline buffered solutions, and under these conditions bacteria do not seem to be killed in the small intestine. In other words, we can interfere with the general biological phenomena of self-disinfection of the contents of the intestinal tract by causing the contents to change from the normal acid to an alkaline reaction. When bacteria are fed with acid milk, the same is true, relatively few reach the caecum, but the same bacteria with alkaline milk soon appear in large numbers in the caecum.[3]

AUTO-DISINFECTION PROCESS OF THE INTESTINAL TRACT

So long as there is a predominance of acid reacting substances in the upper part of the small intestine, the contents contain only a few cocci and seldom if ever are members of the colon family encountered. This persistent acidity of the intestinal contents is brought about under normal conditions by gastric secretory function. So long as the contents of the duodenum and upper jejunum are slightly acid in reaction, the mucous membrane of this part of the tract produces a substance that kills the bacteria. An alkalinization of the contents is accompanied by the appearance of bacteria that are typical inhabitants of lower levels of the intestinal tract and in addition to these, ingested bacteria are not destroyed. Then the bacterial flora of the small intestine is changed both qualitatively and quantitatively, when the reaction changes from acid to alkaline.

Webster and Pritchett[4] investigated the effects of diet upon host resistance in their work with paratyphoid enteritidis infection of white mice. They compared a diet consisting of baker's bread soaked in fresh pasteurized grade B milk, supplemented by semi-weekly feedings of an oatmeal and buckwheat mixture and weekly feedings of dog biscuits with a diet advocated by McCollum. This consisted of wheat 67.5 per cent, casein 15 per cent, milk powder 10 per cent, NaCl 1 per cent, $CaCo_3$ 1.5 per cent, and butter fat 5 per cent. These authors found that the mice fed upon the McCollum diet were more resistant to infection than those fed upon the general diet of bread and milk. We have titrated the amount of acid necessary to bring a given amount of each of these diets to pH 3. This was taken as the acid end of the buffered range and approximates the gastric acidity of mice. Twenty grams of the McCollum diet mixture was ground thoroughly in 100 c.c. of distilled water. Ten grains of stale baker's bread was suspended in 100 c.c. of milk. Chart I shows the results of the experiment in condensed form.

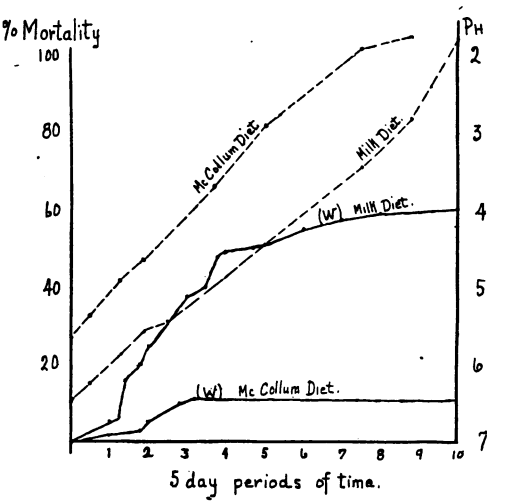

CHART II—Results of experiment with Webster and Pritchett curves of mice mortality.

The McCollum mixture is much more acid than the bread and milk. Chart II shows the same as the previous chart with the curves of Webster and Pritchett Text, Fig. 3 (p. 400), of mice mortality drawn in on the same scale. The amount of gastric secretion necessary to acidify the bread and milk diet is almost double that necessary to bring about the same acidity with the McCollum diet. The

former diet is sufficient for growth and reproduction, etc., but is not sufficient to maintain a gastric acidity necessary to insure the auto-disinfecting mechanism of the contents of the small intestine.

Most of the vitamin containing foods are acid in reaction.[5] Some of the factors in the investigations of such foods might be due to their influence upon the endogenous bacterial flora of the gastro-intestinal tract. This is particularly true in vitamin deficient diets for experimental work. Stransky [6] has observed that rats and rabbits fed upon various vitamin deficient diets all had a rich bacterial flora in the upper part of the intestinal tract. This part of the tract was practically sterile in his control animals.

STUDY OF INFANT DIARRHEAL DEATHS

Summer diarrhea in infants is a common disease. There have been many observations recorded in literature upon the relation between infant diarrhea and external temperature. The writer had the opportunity of analyzing the diarrheal deaths 0–4 years of age in New York City from 1868 to 1924 under the supervision of Dr. Haven Emerson and Professor Earle B. Phelps. Certain portions of this work bear upon the question under discussion. It is a well known fact that the heat regulatory mechanism of the infant is not as perfect as that of the adult. Elevations in external temperature and humidity cause a considerable disturbance in the heat regulatory mechanism in the infant. The gastric secretory function is depressed and there is an elevation of the internal temperature. This has been clearly shown by Demuth [7] in Berlin. The pediatrician usually feeds some form of protein milk or acidified milk in these digestive disturbances in infants during the summer months.

In a recent article [8] the writer explained the beneficial effects, long observed by physicians, of acid-buffered foods in infants as due to the acid content of the food and its effect upon the normal bactericidal mechanism of the intestinal tract. With the depression of gastric acidity due to the elevation of the external temperature and humidity, the infant is unable to acidify the gastric contents sufficient to insure an acid reaction in the upper part of the intestinal tract. This leads to a growth of bacteria in the duodenal region. This is an absorbing area and is normally slightly acid in reaction. Cow's milk mixtures contain a high alkaline buffer; the feeding of these mixtures produce this reaction sooner than the less buffered mother's milk.

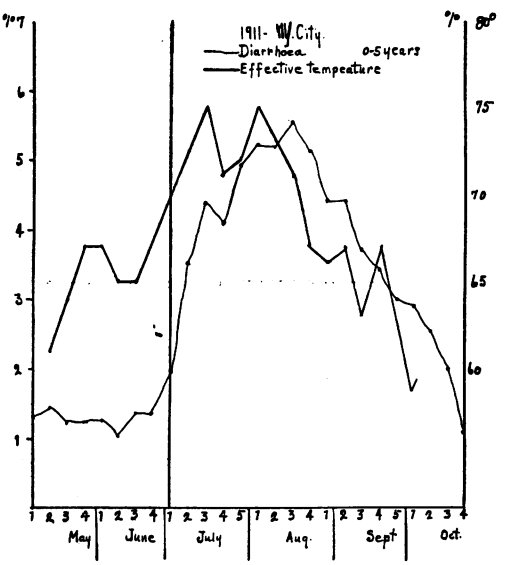

CHART III—Relationship between humidity and temperature.

Chart III shows the relationship between humidity and temperature [9] (effective temperature) and the death rate from diarrhea in infants in New York City in 1911. The death rate is expressed in per cent of the total yearly rate occurring each week. The lag between the temperature and death rate curves is due to the time necessary for this abnormal physiological gastro-intestinal function to cause death in the infant population. Infectious diarrheas due to members of the dysentery group of bacteria find fertile soil in the gastro-intestinal tract under

these conditions. Eguchi [10] records that it takes one-hundredth less than the adult lethal dose of mouse typhoid bacteria to cause death in the young (during the first week of life) of mice and guinea pigs. We do not consider this a specific susceptibility, but think it is due to the lessened amount of gastric hydrochloric acid secretion in these young animals and consequently a great susceptibility to the entrance by mouth of pathogenic bacteria, that are capable of causing disease when present in the small intestine. The common observation in public health work of a diarrhea preceding a typhoid fever epidemic offers some substantiation to our conception of the importance of the normal bactericidal power of the intestinal tract as an important agent in the etiology of infectious disease of this tract.

ACID-BUFFERED MATERIALS IN MAN'S DIET

Fruits and vegetables such as citrous fruits, apples, tomatoes, etc., have been a constant source of acidified food for man. But probably the most important acidified food has been soured milk. The people of Asia and Africa have used soured milk in many forms as a staple part of their diet. This might be due to the fact that milk would usually become acidified very early in these climates, but travelers in Lapland mention the use of soured milk in that cold climate. There must have been some reason based upon experience, other than the preservative qualities of lactic acid, to have led to the use of soured milk as a general diet for man over such a large geographical area. Metchnikoff popularized the use of buttermilk as a result of his investigations of the widespread use of this type of acid milk in the Balkan Peninsula. Three thousand centenarians in a total population of 3,000,000—and these performing duties which would not be assigned to a man of 65 years in America—cannot but be thought of as unusual! Soured milk forms a stable and to a great extent an essential part of their diet and fresh milk is considered unhealthy in the Orient.[11, 12] Dried curds of soured camel's milk shaken in water to the Arab must be even more pleasing than a cool lemonade is to the American. The use of acidophilous milk at the present time seems to be another form of acid-buffered food.

REACTION OF INORGANIC SALTS

One cannot leave this subject without mentioning the possible connection between the absorption of certain inorganic salts and the reaction of the upper part of the intestinal tract. Calcium salts are soluble in acid solutions; in alkaline medium they form insoluble compounds. Many problems of inorganic salt metabolism may be reconsidered, when thought of from the standpoint of the reaction of the duodenum and jejunum. The use of protein milk or of acidified milk in foundling homes has reduced the incidence of rickets.

In a forthcoming issue of the *Klinische Wochenschrift* the writer has discussed this question of the influence of food, gastric function and bacterial flora of the intestinal tract from a broad medical standpoint. In those conditions characterized by a gradual diminution of gastric secretion (a progressive hypochlorhydria leading to an achlorhydria) the possibilities of an acid-buffered diet to correct the progressive alkalinization of the duodenum and jejunum and, thereby, restoring the normal bacterial flora, offers a new field of work for students of nutrition.

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